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PREDICTION OF THE IMPERFECTIONS OF PRESSURE DIE CASTINGS BASED ON THE SIMULATION CALCULATIONS

PREDIKCE VAD TLAKOVÝCH ODLITKŮ NA ZÁKLADĚ SIMULAČNÍCH VÝPOČTŮ

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ABSTRACT: Nowadays, there are quite usually for the optimizing of the production used the simulation programs in the casting practice, which enable to a certain extent the prediction of imperfections already in the phase of the development, what is bringing considerable savings. From this point of view, it is very important as big compliance between the results of the simulation calculations and the reality as possible. With the observation of the compliance of the casting imperfections predicted with the help of simulation program ProCast of the company MECAS ESI s.r.o. and imperfections occurring on a concrete casting is dealing this contribution.

ABSTRAKT: V současné době se ve slévárenské praxi pro optimalizaci výroby již naprosto běžně využívají simulační programy, které umožňují do jisté míry predikci vad již ve fázi vývoje, což přináší značné úspory. Z tohoto hlediska je velmi důležitá, co největší shoda mezi výsledky simulačních výpočtů a skutečností. Sledováním shody slévárenských vad predikovaných pomocí simulačního programu ProCast firmy MECAS ESI s.r.o. a vad vyskytujících se v konkrétním odlitku se zabývá tento příspěvek.

KEY WORDS: pressure die-casting, imperfections, simulation, porosity

KLÍČOVÁ SLOVA: tlakové lití, vady, simulace, porezita

1 INTRODUCTIO

The technology of the pressure die-casting enables the production of the thin-walled castings with very complicated shapes with a very high utility value of the alloys of non-ferrous metals (aluminium, magnesium, zinc etc.). Nowadays, there are made bigger and bigger demands on their quality all time.

The quality of the pressure die-casting is dependent on many factors, e.g. on the type and metallurgical preparation of the cast alloy, on the construction of the casting, on the die casting machine, on the construction of the cast mould, (especially with regard to gate stem and the design of ventilation and tempering system) and last but not least on the operator of the die casting machine.

The precondition of the production of a quality casting is both optimal construction of cast part and of the pressure cast mould, as well as the setting of all the technological parameters. The mistakes in construction are difficult to remove and in some cases they are not removable any more. A suitable tool for their optimization are the simulation programmes, which already enable the prediction of the imperfections up to a certain extent in the phase of development.

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The detection of possible problems and primarily their removal are bringing significant savings for the future. For the cost reduction, there is important as big as possible compliance of simulation calculations and the reality.

This contribution is dealing with the observation of the rate of the compliance of the cast imperfections predicted based on the simulation calculation and of the imperfections detected on the real casting.

The most common imperfections of the pressure die castings are porosity, cold shots and short shots. The porosity of the pressure die castings is caused due to the combination fo the formation of the micro shrinks and voids. The micro shrinks are due to the change of the volume of alloy during the solidification. The voids in the castings come to existence first due to the liberation of the gases dissolved in the alloy during the solidification by reason of the change of their solubility and second there is being closed air in the alloy during the process of the filling of the cavity mould. In the reality, mostly these are solely neither voids, nor micro-shrinks. The micro shrinks are from the thermodynamic point of view a suitable nucleation site for the production of gas holes (pockets.) When mechanism of the production of blows dominates, than the voids have more spherical shape, when the mechanism of the micro-shrinks dominates, the blown spaces are rugged in their shape and copy the dendritical structure of the metal. The voids of spherical shape (blows) do not reduce in contrast with the micro-shrinks so significant the mechanical properties.

2 EXPERIMENT

For the experiment, there was chosen the double-cavity pressure die-casting tool with one hydraulic core, see Fig. 1, of the alloy EN AC - 46000 (EN AC AlSi9Cu3(Fe)). This casting is being cast in the practice on the die-casting machine TOS-TL5-400. The simulation of the filling and solidification of the casting was executed with the help of simulation program ProCast of the company MECAS ESI s.r.o. This program is based on a method of model element FEM and enables modeling of casting and solidification inclusive prediction of casting defaults. The values of all technological parameters as input to the simulation calculation were chosen in a way to be as near as possible to the practice.

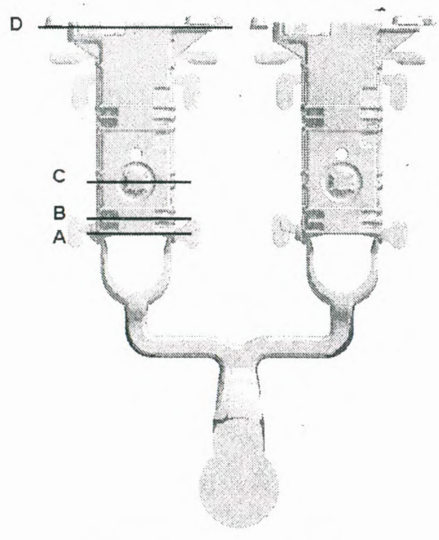


Fig. 1 Pressure casting

From the results of the simulation calculation there is apparent, that during the filling of the mould cavity there is occurring the closing of the air in the casting in the area 1, see Fig. 2. This feature also is being confirmed by Fig. 3, which is graphically representing the areas in the casting at the certain point of time, which have the filling of the elements with metal lower then 50% (e.g. there is closed air in these elements). Based on this criterion it can be expected, that in is going to stay a certain volume of the closed air in these areas. Fig. 4 is demonstrating the time of solidification of the casting in the particular areas, based on which the simulation program predicts the micro-shrinks, see Fig. 5. This criterion is reflecting the micro-shrinks (porosity) arising out of the consequence of the change of volume of cast metal during the solidification. Fig. 5 is demonstrating the elements, where their empty part is bigger then 1%.

After a thorough analysis of the results of the simulation, there were defined the areas with potential appearance of the imperfections. To compare to the reality, there were made sections through these areas in the casting, see Fig. 1. The particular areas were defined on the basis of two criterions. The section in the area A was chosen because of the problems appearing in the practice. The sections B, C were chosen on the basis of the evaluation of the simulation, which predicted closing of the air during the filling in these areas and the section D was chosen on the basis of the predicted micro-shrinks.

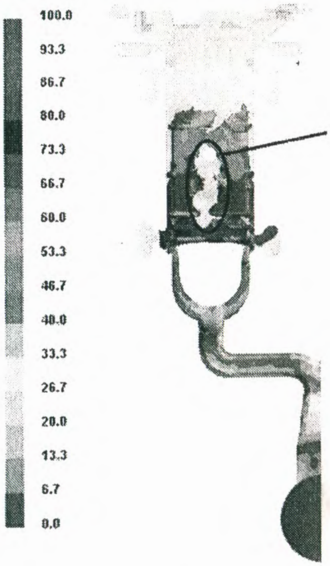


Fig. 2 Velocity of filling in time 0,5178s

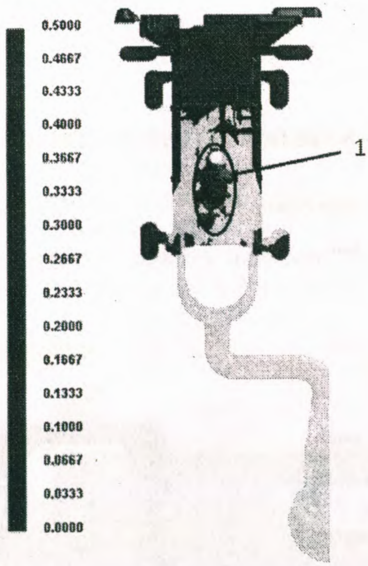
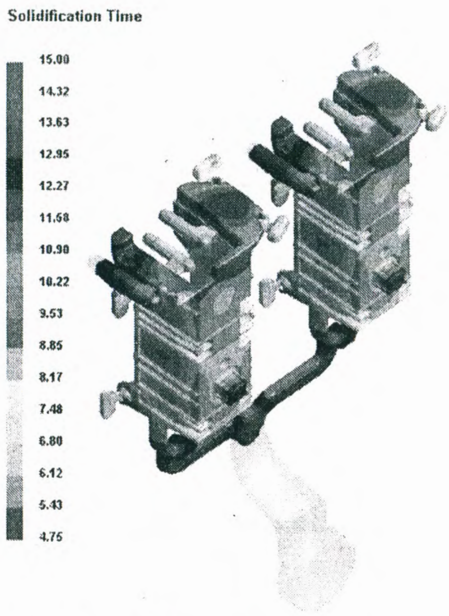


Fig. 3 Voids in the casting – time 0,5178s

The particular sections for observation were prepared in a common metallographic approach. The structure was observed on the light microscope Neophot 21 and evaluated with the help of the software NIS Elements. The porosity at the particular sections was evaluated according to the instruction VDG – Merkblatt P 201. The particular real sections were compared to the results of the simulation.

In section A, the program predicts the micro-shrinks in the marked area, see Fig. 6. From Fig. 3 there is noticeable, that it can partly also come to the closing of the air in this area. Fig. 7 is demonstrating the real section in the area A. In the structure of the section A, there are appearing the fine suspended porosity from the closed air, as well as the micro-shrinks. During the evaluation of the porosity in this section according to the instruction VDG – Merkblatt P 201 there was evaluated as the most critical area the area 7a, see Fig. 7, where the porosity is round approximately 2,1%. In the area 7b, where the simulation predicted the micro-shrinks, the value of porosity is approximately 1,3%.



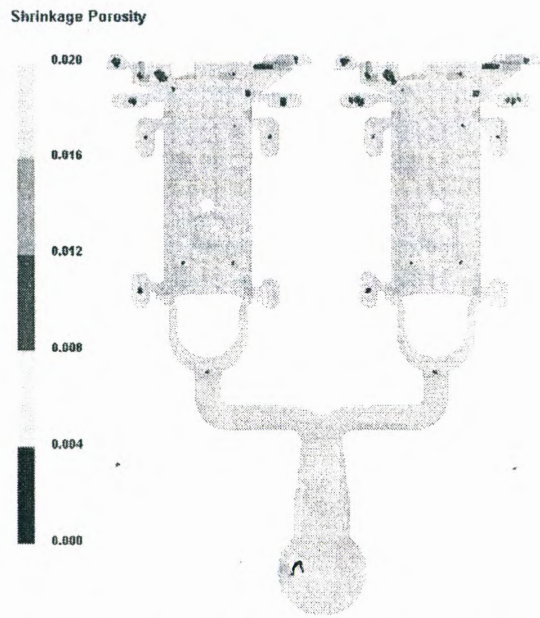
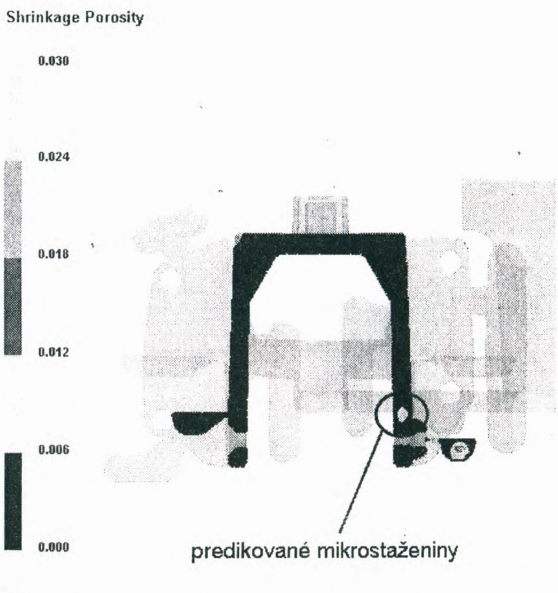


Fig. 4 Solidification time of casting

Fig. 5 Prediction of micro-shrinks in casting



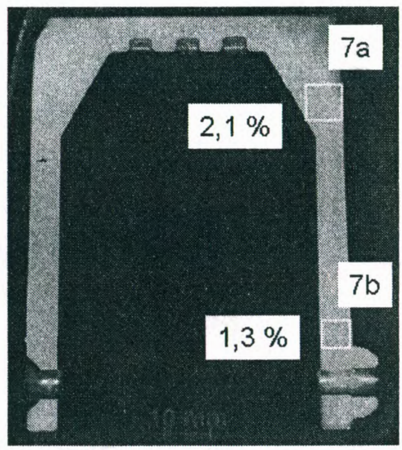
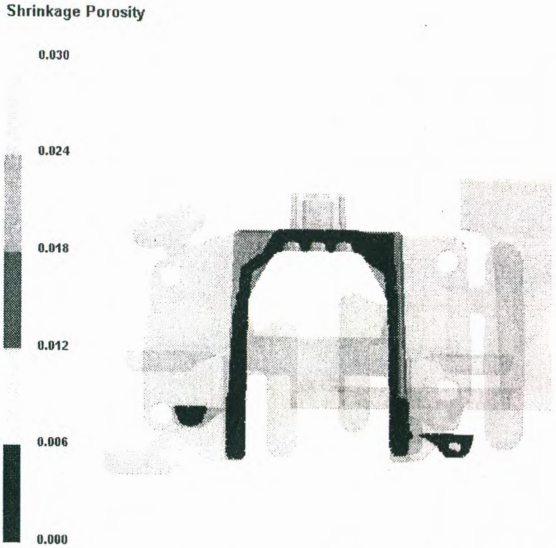


Fig. 6 Section A – prediction of micro-shrinks

Fig. 7 Section A

On Figs. 8 and 9 there is represented a similar situation in the section B. In this area, the program predicted the possibility of closing of air and did not predict the formation of micro-shrinks. In the real section, the fine suspended porosity caused by the closed air appeared and in the area of the riser partly also the micro-shrinks. In the area, which was according to the VDG – Merkblatt P 201 evaluated as the critical one (Fig. 9 – area 9a), there is the total porosity approximately 1,5%. In the area of the riser, see Fig. 9 – area 9a, the value of the porosity is round approximately 1,4 %.



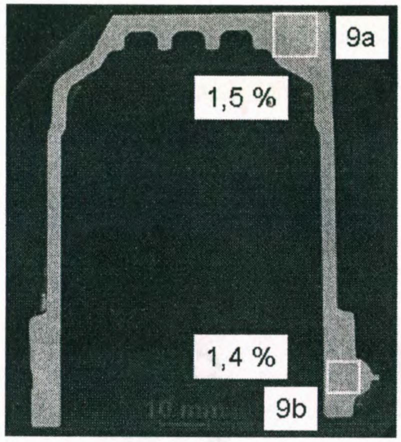
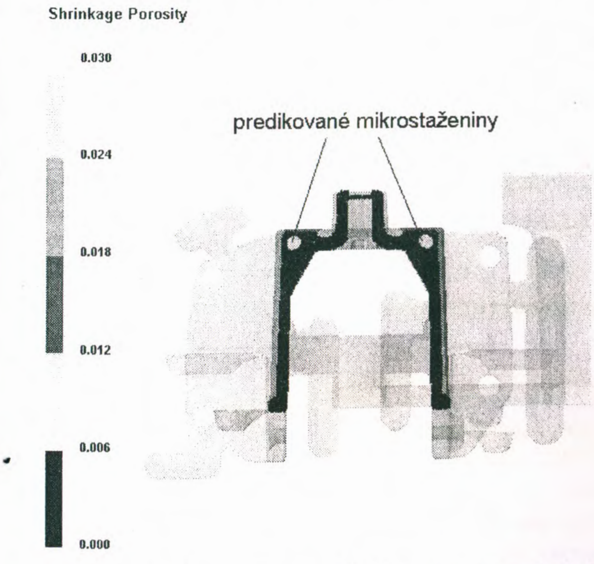


Fig. 8 Section B – prediction of micro-shrinks

Fig. 9 Section B

The section C was lead through the projection, where there comes to significant closing of air according to the simulation programs. The program is indicative of the problem with the closing of air, but is not indicative to where this material gets to at the end of filling. This also is confirmed by the structure of the section C, in which there is occurring a fine suspended porosity from the closed air in the area of the projection, its quantity however is moderate, than one could expect on the basis of the analysis of the results of filling-simulation. The prediction of the micro-shrinks is corresponding to the reality, see Fig. 10 and Fig. 11. In the critical area of the section C, the total porosity is approximately 1,5 %.



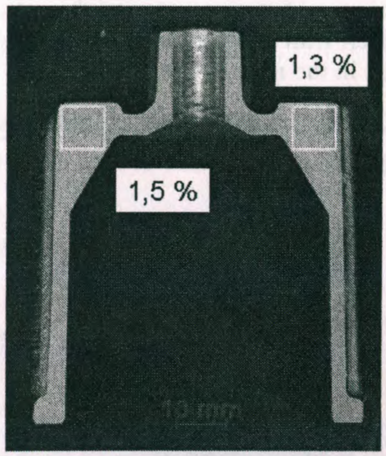
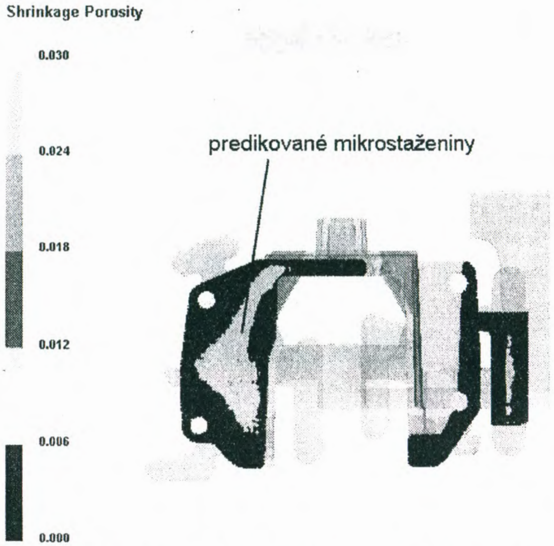


Fig. 10 Section C – prediction of micro-shrinks

Fig. 11 section C

In the area of the section D, the program predicts the most imperfections – micro-shrinks, see Fig. 12. This also was confirmed by the metallographic evaluation of the section D, which showed a higher rate of the imperfections then in the case of previous sections. In this area, besides of the micro-shrinks also the porosity caused by the closed air is appearing, even when this area is ventilated very well. In the area of the section, which already was evaluated according to the above mentioned instruction as a critical one, the total porosity is approximately 2,5 %, see Fig. 13.



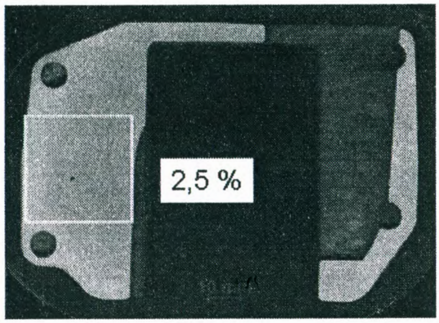


Fig. 12 Section D – prediction of micro-shrinks

Fig. 13 Section D

3 CONCLUSION

The results of the experiment confirm the high compliance of prediction of the micro-shrinks and reality. The problem turns out to be the evaluation of the areas with the closed air. The program shows properly the areas, where this feature occurs, but the definition, where the molten alloy with the closed air is getting to in the final phase of filling, is dependent on the experience of the operator of the simulation program. However it is possible to suppose, that together with the development of the computer technique also this problem is going to be solved in the near future.

The results of the research make for a view, that the prediction of the imperfections by means of the numerical simulation is becoming constantly more and more important during the design and optimization of the cast parts and pressure die-casting moulds.

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